Validation of the GLAST Burst Monitor Instrument Response Simulation Software

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Abstract. The GLAST Burst Monitor (GBM) comprises 12 NaI and 2 BGO detectors dispersed about the GLAST spacecraft. The GBM instrument simulation software must generate an accurate response function database for all detectors in their flight configuration to optimize the mission science return. Before science analysis codes use the response database, we must confirm that our simulation codes and models can reproduce laboratory observations. To validate the simulation effort, Monte Carlo results are compared to calibrated laboratory measurements collected with a variety of radiation sources.

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VALIDATION APPROACH AND RESULTS

The GLAST Burst Monitor (GBM) comprises 12 NaI and 2 BGO detectors dispersed about the GLAST spacecraft[1][2]. The detectors will collect photons arriving directly from the source and also photons that scatter off instrument and spacecraft components. We use GEANT4, detailed detector and spacecraft models, and input from real measurements to simulate the instrument response. To validate the simulation effort, Monte Carlo results are compared to calibrated laboratory measurements collected with a variety of radiation sources. The first level of validation occurs for individual detectors irradiated in a laboratory at different incident energies and angles. A second level of validation is performed at the spacecraft level, where the entire spacecraft is irradiated from a variety of positions with all detectors mounted in their flight orientation. At present, we have completed measurements of individual detectors in the laboratory for the first level of validation and we present initial results of comparisions to the simulated data.

Detailed models of the GBM NaI detectors and BGO detectors are used for simulations with GEANT. A cross-section view of the NaI model is shown in Figure 1. The most obvious components are the PMT, crystal and surrounding packaging, and external housing. The BGO detector model is similar, but with a much larger crystal volume and two PMTs. Great care is taken to reproduce the materials and geometry used in the real detectors, especially around the NaI and BGO crystal volumes. This high level of detail in the GEANT model is required to reproduce contributions to the spectrum from scattering and pair-production processes.

The GEANT simulation and detector models are validated by comparing simulation results to data measured in the laboratory. A complete model of the laboratory where the measurements were taken is used to reproduce contributions to the spectrum from scatter events. The model includes the floor, walls, ceiling, large furniture, detector stand and holder, and the source stand and holder. Measurements were taken for a variety of radioisotopes for the NaI and BGO detector flight units at MPE in Germany. For simulations, the room is illuminated isotropically with the appropriate photon energy spectrum for each radioisotope.

Comparisons of measured and simulated data using the complete laboratory model are shown in Figure 2 for the NaI detector illuminated by ^{137}Cs. Simulated data are normalized to the measurement livetime. The measured energy dependent resolution is applied to the simulated energy deposit in the NaI crystal to reproduce the detector resolution.

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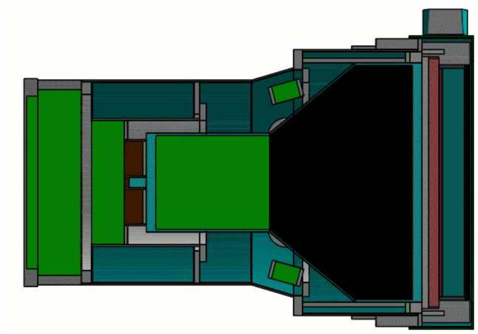

FIGURE 1. Cross-section view of the GEANT4 NaI detector model.

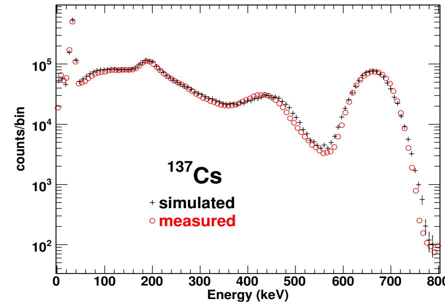

FIGURE 2. Simulated and measured ^{137}Cs data for a NaI detector.

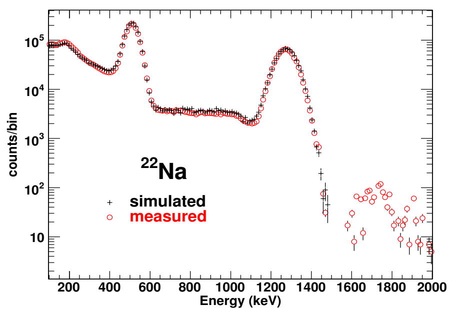

FIGURE 3. Simulated and measured ^{22}Na data for a BGO detector.

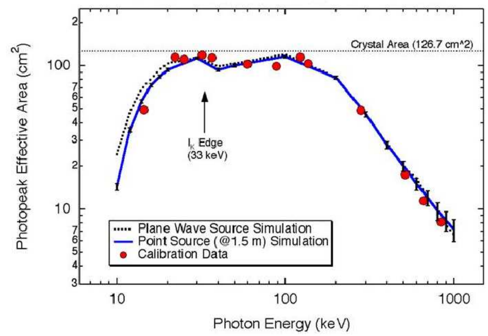

FIGURE 4. Comparison of measured data, simulated point source, and simulated plane wave source, for a NaI detector and normal incidence angle.

In general, the simulation results reproduce the measured data quite well. Illuminating the room isotropically is critical for reproducing the backscatter peaks. Data were collected from about seven radioisotopes to sufficiently cover the energy range. There are a few discrepancies to be understood, such as apparent missing low energy lines in the simulation for ^{241}Am and ^{109}Cd, and a slight offset in the profile of the Compton edge. BGO validation results are shown in Figure 3 for the BGO detector illuminated by ^{22}Na. As with the NaI results, the measured detector resolution was applied to the simulated data. The BGO detectors are intended to operate in the 150 keV to 30 MeV range. Simulation comparisons are peromed for the low energy results from laboratory calibration sources. Higher energy calibrations ($>$2.6 MeV) are performed at an accelerator facility and do not lend themselves to straightforward validation simulations. In Figure 4, the photopeak effective area for a single GBM NaI detector is shown as a function of energy for measured data, simulated plane wave, and simulated point source at 1.5 meters and normal incidence.

A second level of validation will be performed at the spacecraft level, with all detectors mounted in their flight positions. We do this as a way to validate the model of the spacecraft itself, because the detectors are mounted at different angles with a variety of look directions, and because the view of detectors can be obstructed by various objects depending on the source position. The spacecraft will be illuminated with a source, and the measured energy deposits in each detector will be compared to the simulation results. Spacecraft level validation measurements will occur in the near future[3].

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